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ABSTRACT

The computer assisted problem solving system (CAPS) described in this booklet administered "homework" problem sets designed to develop students' computational, estimation, and procedural skills. These skills were related to important concepts in an introductory statistics course. CAPS generated unique data, judged student performance, provided hints about problem solving strategies, and stored relevant performance data. A PDP-10 computer, with hard copy and CRT terminals, was programmed to interact with students in an instructional mode. Courseware was coded in interactive Fortran and packaged so that additional items could be added easily to the existing problem set. After three semesters of implementation, student reaction to CAPS is generally favorable. (Author)

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CENTER FOR THE STUDY OF READING

Technical Report No. 56

COMPUTER ASSISTED PROBLEM SOLVING IN AN INTRODUCTORY STATISTICS COURSE

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Abstract

The computer assisted problem solving system (CAPS) administered "homework" problem sets designed to develop students' computational, estimation, and procedural skills related to important concepts of an introductory statistics course. CAPS generated unique data, judged student performance, provided hints about problem solving strategies, and stored relevant performance data. A PDP-10 computer, with hardcopy and CRT terminals, was programmed to interact with students in an instructional mode. Courseware was coded in interactive Fortran and packaged so that additional items can be added easily to the existing problem sets. After three semesters of implementation, student reaction to CAPS is generally favorable.

Computer Assisted Problem Solving in an Introductory Statistics Course

The computer assisted problem solving system (CAPS) was designed to help statistics students acquire computation skills and experience in solving a set of rather traditional statistical exercises. CAPS is but one component of an instructional systems approach used to teach an introductory statistics course and, as such, needs to be described within the context of the course.

Organization of the Course

The course serves a large number of students with a wide range of abilities, professional aspirations, and specialities. Some students who enroll in the course, for example, have not had a mathematics course since high school, while others have recently completed college level courses. Some enter the course with a crippling fear of statistics, while others approach it with breezy confidence.

In response to these needs, the logistics of the traditional lecture-discussion course was modified and some new components were added. The two hours per week lecture-discussion sessions, and the primary text (Glass & Stanley, 1970) were retained. The lectures were "tightened up" somewhat, and the discussion typically was used to clarify points rather than "enrich" the content. In preparation for the class section following lectures, about four days later, all students were required to take a quiz at their convenience on the PLATO IV CAI system (Paulson, 1978). If the student obtained a score of 85-100% correct on a 10-20 item quiz, attendance at the next session was

usually optional; a score of 70-85% correct meant that the student was strongly encouraged to attend; and a score below 70% required the student to attend. This class session was usually a problem-oriented, informal session.

To assist the student who had difficulty reading the primary text and needed more examples of statistics principles, two of the instructors prepared a programmed text and workbook (Armbruster & Dastrup, 1976). Finally, all students were required to solve 20 problems on the CAPS system. This requirement replaced the typical homework problem sets. The problems were designed to test students' abilities to select, compute, and estimate statistics with an emphasis on applying them. The CAPS items complemented the PLATO quizzes in that the quizzes tested principles and concepts while the CAPS items stressed computational exercises related to the concepts.

How CAPS Works

The CAPS procedure started for a student when she took her instruction sheet and signed on at a DEC writer or INFOTON CRT terminal connected to a PDP-10 system. In an interactive mode, the student received information on how to use the system, and a combined index and Progress Report page of all the problems. The student first selected a problem to solve which was printed, after which she signed off the system and attempted to solve it.

Later she signed back onto the system and recorded her answer. If the computer judged the answer to be correct (within a tolerance described in the problem) the student was returned to the index page; if it was incorrect, a problem solving hint was provided and the student worked until the problem

was solved correctly or the student received four hints. This procedure is illustrated in Figure 1.

Insert Figure 1 about here

Problem Solving Feedback to Students

The CAPS items were classified into two types: (1) estimation problems requiring approximation of a statistic from a graphic representation of data and (2) computation problems for which there were preferred strategies of solution. The basic instructional design of CAPS was to incorporate feedback strategies for each of these two types of problems.

For computational problems, four levels of problem solving strategies (hints) were developed. The first hint was simply a restatement of the problem. The excess verbage was stripped away and the item was organized under the labels "Given" and "Problem." Hint 2 was a strategy for working the problem listed in a series of steps. The strategy is similar to what a tutor might use when working with a student. Hint 3 provided a solution to a similar problem, including intermediate solutions congruent with the steps provided in Hint 2. Hint 4 presented the solution, with intermediate steps, to the given problem.

To make the hints more meaningful and to diminish the tendency of some students to share answers, the computer generated unique problems for each student. The basic item format remained the same but the data base changed. Each problem, then, is a one item domain referenced test or an item form, as described by Hively et al. (1973). In this way, students could call for as many Hint 3's as they wished and see the problem solution with different data each time.

Two of the problems were designed to sharpen a student's ability to estimate statistics from a large array of data. In one problem, ten unique histograms with approximately 60 entries each were displayed, and the student was required to estimate the mean and standard deviation of each with tolerances of approximately 3% and 10% respectively. At least 14 correct estimates of the 20 possibilities were required before the problem was judged to be completed successfully. About half of the ten histograms represented distributions with approximate normal distributions while the remaining ones were skewed and/or bimodal.

In another problem, ten unique scatterplots with about 25 entries each were displayed, and the students were required to estimate the Pearson product-moment correlation coefficient within a tolerance of .05. At least seven correct estimates of the possible 10 were required to complete the problem successfully. The coefficients ranged approximately from -1 to +1.

One other type of problem tested procedural skills. The students were required to locate Chi, F and T statistics in a table with prescribed probability and degree of freedom parameters. Twelve items were presented and the students were required to answer them all correctly.

The remaining problems dealt with (1) computation of descriptive statistics such as mean, centile rank, and variance, (2) identification and computation of an inferential statistic, such as differences between the means of dependent samples, and (3) correlation and estimation. The index of problems, with abbreviated titles, is shown in Figure 2.

Insert Figure 2 about here

Students were required to solve all 20 problem types during the semester using no more than one hint on each before they could take the final exam. Problems could be selected as often as necessary to meet this requirement.

To date, CAPS has been used for two semesters with approximately 100 students. The remainder of the paper discusses the preparation and design of the software and presents evaluation-type data from students.

Hardware - Software

A PDP-10 timesharing computer (Digital Equipment Corporation) was chosen to deliver CAPS for two reasons. First, another timesharing computer based education system had already been used sucessfully for another course management project (Alessi et al., 1976; Anderson et al., 1974, 1975 a,b). We wished to investigate the feasibility of instructional delivery on another system. Second, the PDP-10 provided a FORTRAN compiler, while PLATO provides only the TUTOR language (Sherwood, 1974) which is available only on PLATO. We wished to test the feasibility of an instructional system using the more common FORTRAN language.

The PDP-10 is a programmer's computer with very powerful software and is correspondingly difficult to use. We were able to use certain system features, however, to make the PDP-10 usuable by students with minimal instruction. A student needed only to be able to sign on. From there, the correct programs are automatically executed and the student automatically signed off at the end of the session. Subroutines in the program check the form of student responses (i.e. alphabetic versus numberic) and give the student meaningful feedback when incorrect, rather than the usual coded system error messages meant for programmers.

The CAPS programs consist of a main program with a number of overlaying subroutines. The subroutines perform the following functions: (1) The item subroutines generate data for and display the 20 items (each item being a separate subroutine). The data for any item are generated by a random number generator seeded by a function of the student number, item number, and how many times the student has tried that item. With such a method of data generation, it is possible for an instructor to obtain the exact data a particular student received on any try of an item. (2) The student input subroutine is responsible for accepting all student inputs, checking their form, and providing help if wrong. (3) Two different logoff subroutines log the student off either at the student's request (a single keypress available at any time) or at the end of the session. (4) The answer judging subroutine compares a student response to the correct answer calculated by the individual item subroutines, and judges it to be correct or incorrect. (5) A few subroutines segregate code that is not standard ANS FORTRAN, which would require modification on other computers. (6) A 'pause' subroutine stops execution of the program to give students time to copy information from the terminal before it disappears. Most students worked at CRT terminals, and the item display, which generally fills a screen, would be partially lost when logout occurs. (7) An information subroutine provides students with a short lesson on the use of the terminal and the CAPS system. (8) An instructor subroutine provides a facility to inspect any item as it appeared for any student on any try.

Subroutines are overlayed because the entire set of programs is too big to fit in central memory at one time. With overlaying, no student session

occupies more than 16.5 kilobytes of core for the main program and necessary subroutines. The logoff and pause subroutines are coded in MACRO-10, PDP-10 assembly language. All others are coded in FORTRAN.

The main program, always called at login, performs a variety of functions. It accesses an individual student's record (determined by the student inputting her/his student number and password) and updates them at logoff. It displays messages from the instructors targeted for any individual student or the entire class. It displays the index when appropriate, or calls the necessary item subroutine; lastly, it accesses the logoff subroutines.

Student records are kept in a direct-access disc file. The student number given at login corresponds to the same number record in the file. The record contains the student's password; scores, level of completion, and number of tries for each of the twenty items; whether the student has a message not yet seen, and whether the student has seen the introductory information on the use of the terminal and CAPS. The record is read in at signin and written out both at logoff and whenever a significant activity is completed, such as completing an item. The latter is done to protect against the loss of data due to system or terminal failure.

Evaluation

In addition to performance data described previously, we periodically inspected the data file to track chronologically the sequence of items selected and hints required on trials. The procedure is to print the data file every two weeks during the first 12 weeks and to print it every few days during the last weeks of the semester as student activity increases.

The students also completed two questionnaires (at mid term and the end of the semester) during the course of the semester which included items on all aspects of the course including the CAPS system. Both Fall semester and the first Spring semester questionnaires were administered through the PLATO system used for quizzes during the semesters.

We have described the revised version of CAPS which was used during the second semester of its operation. The evaluation of performance data from the first semester, which included student questionnaire results and an analysis of costs involved, resulted in several programming changes. Most of the changes were directed at 'student convenience' with little attention to cost factors. However, the changes did result in a 40% decrease in the cost per completed item.

Originally, the strategy for CAPS was that a student would select an item and remain on the system while doing the calculations. If the answer was judged as incorrect, the student was shown the first hint and then logged off the system to rework the item. After a second incorrect answer only the second hint was shown and the student was signed off. This 'sign-in, record an answer, receive a hint if wrong and be signed off' cycle might be repeated four times before the student could select another item. Since the student was required to repeat the item if more than one incorrect response was given, it was felt that hints 2, 3, and 4 should be available after the second incorrect response rather than require four separate sign-ins to inspect all hints.

Another change was to require that the students work the problems off line. Rather than see the item and work it immediately, we programmed the

computer to log the student off after a two minute pause. This meant that we could delete the calculator subroutine that we had made available in an earlier version. We felt justified in our decision to discontinue using the calculator since questionnaire results indicated that more than 50% of the students never used the calculator and only 10% used it regularly.

These changes plus the deletion of two items related to concepts not taught in the introductory statistics course resulted in a decrease in cost per item and a decrease in computer connect time per item during the second semester of operation. A summary of cost/time data for the first semester and the first half of the second semester is shown in Figure 3. The basic charges for PDP-10 use include: $2.40 per connect hour, $1.50 per kilocore hour, and $60.00 per CPU hour. In general, the average charge is about $5.00 per hour of terminal use during 'normal' editing and/or execution of programs.

Insert Figure 3 about here

As one might expect, student reaction to CAPS has ranged from very positive to assertatively negative. The range of reactions is captured by questionnaire data in response to the following multiple choice item embedded among others related to course components. The responses were scaled from +2 to -2.

The CAPS problems were:	(Assigned Scale)
a. very detrimental	(-2)
b. detrimental	(-1)
c. neutral	(0)
d. beneficial	(+1)
e. very beneficial	(+2)

The scaled data for end-of-semester frequencies were compared to the data for other course components. All items had the same response choices listed above for the CAPS item. The scaled data resulted in the following rankings:

	Fall Semester		Spring Semester	
Rank	Component	Rank	Component	Rank
1	Workbook	1.74	Workbook	1.80
2	Lecture	1.25	Lecture	1.10
3	PLATO Quizzes	1.18	Problem Session	.80
4	CAPS	1.04	PLATO Quizzes	.76
5	Problem Session	.88	CAPS	.34
6	Primary Textbook	.07	Primary Textbook	-.90

In an open ended question, students were asked to give their reactions to the course components. Students' responses indicated that the most dissatisfaction with the CAPS system stems from the inconvenience of locating an available terminal at a convenient time. At least two students rented terminals for home-use since they are available at a nominal cost.

While our strategy of allowing only one item at a time to be available for a student was designed so that 'students would keep current with the lecture topic,' students who opted for fewer--but longer--sessions had some difficulty in relating CAPS problems to class discussions. Periodic inspection of student performance data indicated that some students were 3 - 4 topics behind class discussions. Consequently, instructors did not discuss related CAPS problems during the lectures.

Most student reaction to CAPS, however, was positive. While some students did not 'keep current,' most students reviewed several items prior to the final exams. All students successfully completed all CAPS items prior to the final exam for both semesters. One particular student reaction deserves mention because it captures one intent of CAPS: "The CAPS problems are useful. In areas I am confident, they lend support to confidence. In problem areas, they clarify methodology (Fall semester)."

Summary

Although we have employed an interactive computer system normally used for coding and executing programs, the CAPS system can be used for individual problem solving, with computer assistance if necessary, and can be used for individual tutorial sessions with the instructor if desired. Although individual problems were not always integrated into the lectures--nor was that the intent--the CAPS system, by providing concrete examples of concepts taught in class, was an integral part of these sections of the introductory statistics class.

During the Fall, 1977 semester, the CAPS system was modified so that the item subroutines formed the basis of a problem generating system that was used without student contact with the computer. The instructor was able to produce individual problems for his students with separate answers for his own use. These minor modifications required that the instructor interact with the computer while the problems were being produced. We speculate that the CAPS system could be modified further so that the items could be run in 'batch' mode rather than just interactively.

The present format of CAPS could be used by other subject matter disciplines which normally assign problem sets emphasizing application. Such content areas might include accounting, physics, and chemistry.

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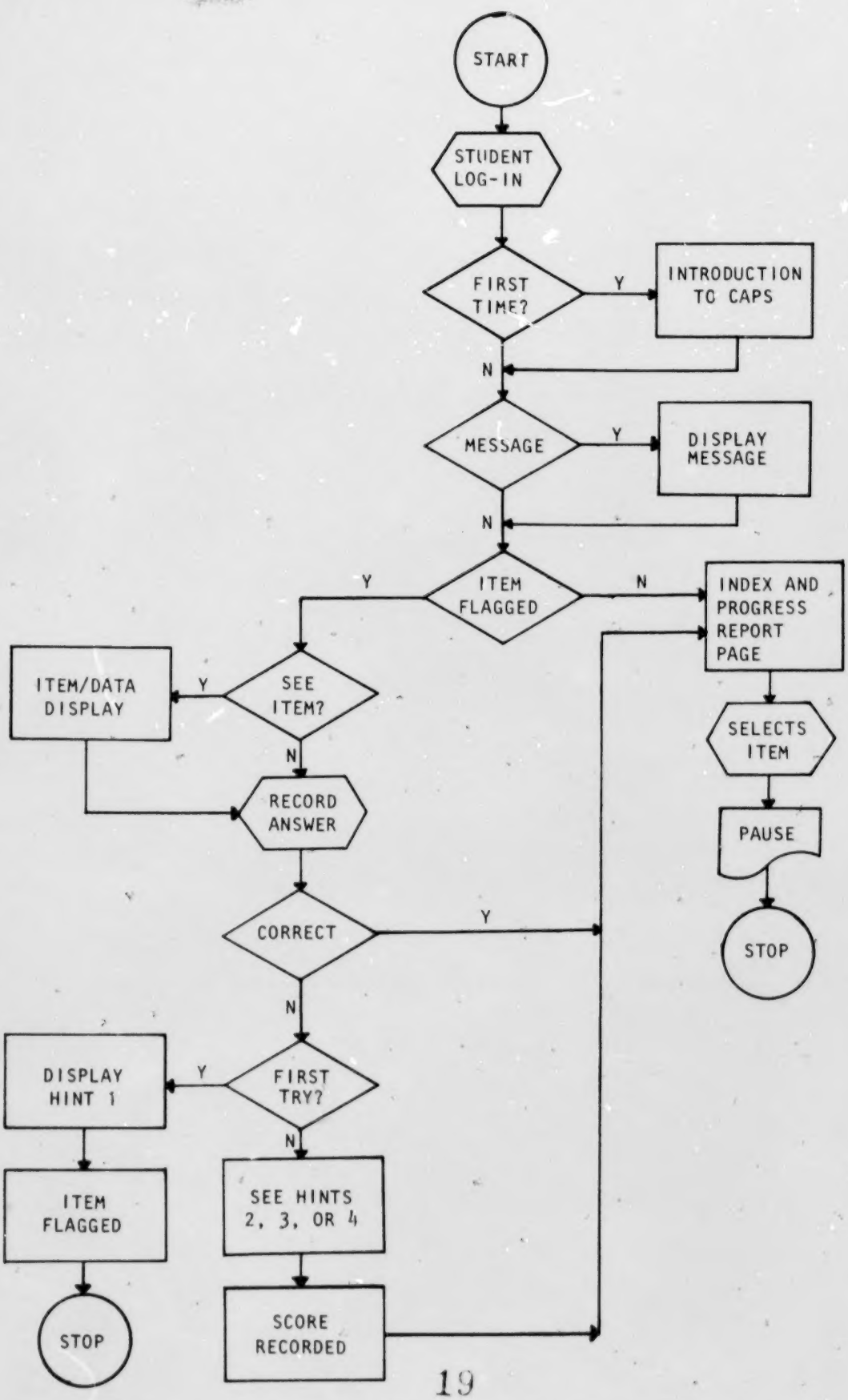
Figure Captions

Figure 1. The CAPS procedure.

Figure 2. Individual record--Index of problems.

Figure 3. PDP-10 cost time data.


START
STUDENT LOG-IN
FIRST TIME?
Y
INTRODUCTION TO CAPS
N
MESSAGE
Y
DISPLAY MESSAGE
N
ITEM FLAGGED
Y
N
INDEX AND PROGRESS REPORT PAGE
SEE ITEM?
Y
ITEM/DATA DISPLAY
N
SELECTS ITEM
RECORD ANSWER
PAUSE
CORRECT
Y
STOP
N
DISPLAY HINT 1
Y
FIRST TRY?
N
ITEM FLAGGED
SEE HINTS 2, 3, OR 4
STOP
SCORE RECORDED

Index of Problems

Topic	Hints	Topic	Hints
1. Centile rank		2. Percentile	
3. Mean		4. Corrected mean	
5. Median		6. Snandard deviation	
7. Corrected varience		8. Z-score	
9. T-score		10. Histograms	
11. Weighted t-score		12. Normal curve - SD	
13. Normal curve - N		14. 2 group inference	
15. 2 group inference		16. Tables	
17. Regression		18. Correlation	
19. Prediction		20. Scatterplots	

Fall Semester - 1975

Month	Total cost	Terminal hours
Sept.	$ 263.29	79.00
Oct.	218.53	63.64
Nov.	285.14	83.35
Dec.	534.80	170.74
Total	$1301.76	396.73

Number of items completed:

750

Average per completed item:

Cost - $1.74

Hours - .53

Instructor/programmer:

Total cost - $53.74

Total hours - 12.16

Spring Semester - 1976 (partial)

Month	Total cost	Terminal hours
Jan.	$ 1.11	.17
Feb.	171.74	55.45
Mar.	38.82	11.93
Total	$211.67	67.55

Number of items completed:

217

Average per completed item:

Cost - $ .98

Hours - .31

Instructor/programmer:

Total cost - $48.66

Total hours - 11.18

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